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PREFERENCES FOR AND AGAINST STIMULI PAIRED WITH FOOD

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Pigeons were presented with a concurrent-chains schedule in which terminal-link entries were assigned to two response keys on a percentage basis. The terminal links were fixed delays that sometimes ended with food and sometimes did not. In most conditions, 80% of the terminal links were assigned to one key, but a smaller percentage of the terminal links ended with food for this key, so the number of food reinforcers delivered by the two alternatives was equal. When the same terminal-link stimuli (orange houselights) were used for both alternatives, the pigeons showed a preference for whichever alternative delivered more frequent terminal links. When different terminal-link stimuli (green vs. red houselights) were used for the two alternatives, the pigeons showed a preference for whichever alternative delivered fewer terminal links when terminal-link durations were long, and no systematic preferences when terminal-link durations were short. This pattern of results was consistent with the predictions of Grace's (1994) contextual choice model. Preference for the alternative that delivered more frequent terminal links was usually stronger in the first few sessions of a condition than at the end of a condition, suggesting that the conditioned reinforcing effect of the additional terminal-link presentations was, in part, transitory.

Key words: conditioned reinforcement, choice, concurrent chains, reinforcement probability, key peck, pigeons

One common technique for studying conditioned reinforcement is to use a concurrent-chains procedure with variable-interval (VI) schedules as initial links and VI or fixed-interval (FI) schedules as terminal links (see Fantino, 1977, for a review). The stimuli associated with the terminal links (often different keylight colors in studies with pigeons) could be expected to function as conditioned reinforcers because they lead to food once the terminal-link schedule is completed. If identical VI schedules are used as the initial links, the relative response rates during the initial links can be treated as measures of preference for the conditioned reinforcers presented in the terminal links. This notion is implied by some theories of concurrent-chains performance, such as Fantino's (1969) delay-reduction theory. According to delay-reduction theory, the reinforcing strength of each terminal-link stimulus depends on the reduction in time to primary reinforcement that its onset signals. For example, suppose that the two terminal-link stimuli are red and green response keys. If the red key signals a 40-s reduction in time to food and the green key signals a 20-s reduction, delay-reduction theory predicts that, during the initial links, a subject will respond twice as rapidly on the schedule that leads to the red key.

One problem with this analysis of concurrent-chains performance is that it is often difficult to distinguish the effects of conditioned reinforcement from those of primary reinforcement. Thus, in this example, one could argue that the preference for the left key does not occur because the red keylight is a stronger conditioned reinforcer, but because the left schedule delivers the primary reinforcer, food, at a faster rate. Indeed, a more general version of delay-reduction theory (Squires & Fantino, 1971) considers both the conditioned reinforcing effects of the terminal-link stimuli and the overall rates of primary reinforcement. Similarly, Killeen's (1982) incentive theory includes the assumption that conditioned and primary reinforcers have distinct and separate effects on choice in concurrent-chains schedules. Although these models have made reasonable predictions for a variety of experiments with concurrent-chains schedules, it is nevertheless true that when every terminal link includes both a conditioned reinforcer and a

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primary reinforcer, it is difficult to separate their effects.[1]

A useful strategy for separating the effects of conditioned and primary reinforcers is to present them at different rates, by including some terminal-link presentations that do not end with food (e.g., Dunn & Spetch, 1990; Spetch, Belke, Barnet, Dunn, & Pierce, 1990). This strategy was used in a study by Williams and Dunn (1991), in which pigeons responded on two white keys during the initial links, and the same stimulus (a green center key) was used for both terminal links. In some terminal links, pecks on the green key led to food on an FI 20-s schedule, but in others, the green key was darkened after 20 s, and no food was presented. Throughout the experiment, the left and right schedules always delivered the same number of food reinforcers, but the number of conditioned reinforcers (green-key presentations) varied across conditions. The pigeons consistently showed a preference for whichever alternative delivered terminal links at a higher rate, even though all the extra terminal links ended without food. Williams and Dunn concluded that, because the rate of primary reinforcement was equated for the two alternatives, these results demonstrated that the terminal links without food still served as reinforcers.

However, this preference for the alternative that delivers more terminal links (even though the extra terminal links end without food) evidently requires that identical stimuli be used in both terminal links. Dunn, Williams, and Royalty (1987) used a fairly similar procedure, but different stimuli were used for the two terminal links. In contrast to the results of Williams and Dunn (1991), Dunn et al. found a preference for whichever alternative delivered the *lower* rate of terminal links without food. They concluded that the terminal-link stimuli were ''devalued'' when they did not end with food, and whichever terminal-link stimulus had more nonfood presentations suffered greater devaluation. Nevertheless, Dunn et al. concluded that their findings provided support for the concept of conditioned reinforcement because, as in the Williams and Dunn experiment, the rate of food presentations was equated for the two alternatives. They therefore reasoned that any preference for one of the two alternatives must be due to differences in the strengths of the conditioned reinforcers. As they noted, their results are consistent with the common view that the strength of a conditioned reinforcer depends on the probability that it will be followed by a primary reinforcer.

One purpose of the present experiment was to determine whether the different results found by Williams and Dunn (1991) and by Dunn et al. (1987) could be observed in a within-subject comparison. This was done by including some conditions that used the same stimulus (orange houselights) in both terminal links and other conditions with two different stimuli (green vs. red houselights) in the two terminal links. (The former will be called the *orange conditions* and the latter the *green-red conditions*.) In most conditions, one alternative delivered 80% of the terminal links, but only 20% of these terminal links ended with food. The other alternative delivered the other 20% of the terminal links, but 80% of these terminal links ended with food. In this way, the number of food reinforcers was kept equal for the two alternatives, but one alternative delivered four times as many conditioned reinforcers (terminal-link stimuli) as the other. In addition, the lengths of the fixed-time (FT) schedules used as terminal links were varied across conditions to determine how terminal-link duration would affect preference.

The results were used to test the predictions of Grace's (1994, 1996) contextual choice model, which has been shown to make accurate predictions for a large number of studies that used concurrent-chains procedures. A detailed explanation of this model will not be presented here, but a brief overview is needed in order to explain the mod-

[1] Fantino's (1969) experiment on concurrent-chains schedules included a condition in which rates of primary reinforcement were equal for the two alternatives, and pigeons showed nearly exclusive preference for the alternative that delivered only 25% of the terminal links. This result could be taken as evidence that choice is not determined by the rate of conditioned reinforcement (i.e., the rate of terminal-link entries), except for one complication: The terminal-link schedules were not equal. The terminal-link schedule on the preferred key was VI 30 s, compared to VI 90 s on the other key. Clearly, the difference in terminal-link schedules had a large effect on choice, which may have overshadowed any effect of the different rates of terminal-link entry.

el's predictions for this experiment. Equation 1 is the basic equation of the contextual choice model:

$$\frac{B_L}{B_R} = b\left(\frac{r_{1L}}{r_{1R}}\right)^{a_1}\left(\frac{r_{2L}}{r_{2R}}\right)^{a_2(T_t/T_i)^k}. \quad (1)$$

B_L and B_R are initial-link response rates for the left and right alternatives, respectively. The parameter b reflects any bias for the left or right alternative, r_{1L} and r_{1R} are the mean initial-link reinforcement rates for the two alternatives, and r_{2L} and r_{2R} are the mean terminal-link reinforcement rates for the two alternatives. The exponents a_1 and a_2 reflect the subject's sensitivities to the initial-link and terminal-link schedules, respectively. T_t is the average terminal-link duration, T_i is the average initial-link duration, and k is a scaling constant. According to this model, choice in a concurrent-chains procedure is determined by at least three important factors: (a) the schedules in the initial links (r_{1L} and r_{1R}) and the subject's sensitivity (a_1) to differences in these schedules, (b) the schedules in the terminal links (r_{2L} and r_{2R}) and the subject's sensitivity (a_2) to differences in these schedules, and (c) the relative durations of the initial and terminal links, as represented by the exponent T_t/T_i. This exponent is included to give more weight to whichever link lasts longer.

The model's predictions for the present experiment can be derived as follows. For the orange conditions, in which the same stimulus is used as the terminal-link stimulus for both alternatives, we can assume that the sensitivity parameter a_2 will be low. In the limiting case, if subjects do not discriminate between left and right terminal links at all, a_2 will equal 0, and therefore the last term in Equation 1 becomes 1, and preference will be solely determined by the relative rates of conditioned reinforcement, r_{1L} and r_{1R}. If a_2 is 0 or close to 0, two predictions follow: (a) Subjects should show a preference for whichever alternative has the higher rate of conditioned reinforcement (i.e., the higher rate of terminal-link entries), and (b) the duration of the terminal links should have little or no effect on preference (again, because the last term in Equation 1 is close to 1).

For the green-red conditions, subjects should be better able to discriminate between the two terminal links, so a_2 should be larger. Precise quantitative predictions would depend on the values of the parameters b, a_1, and a_2, which cannot be known in advance. However, the following general predictions can be made for the conditions in which the left alternative delivers 80% of the terminal links, but only 20% of these terminal links end with food: (a) Subjects should show less preference for the left alternative than in the orange conditions. If a_2 is large compared to a_1, subjects may now show a preference for the right alternative, because four times as many right terminal links end with food. (b) Whether or not this happens, preference in the green-red conditions should vary with the duration of the terminal links, because duration will affect the ratio T_t/T_i. Specifically, the reinforcement percentages in the terminal links should have more weight when the terminal links are longer. Therefore, subjects should show greater preference for the terminal link that delivers the higher percentage of food reinforcers when the terminal links are long than when they are short.

In the orange conditions, the pigeons might have some ability to discriminate between the left and right terminal links, even though the same stimuli (orange houselights) are present in each. If so, then a_2 will be greater than 0 in the orange conditions, and it will be more difficult to observe a difference between the orange and the green-red conditions. Yet even if a_2 is greater than 0, as long as there is some difference in a_2 between the orange and green-red conditions, the contextual choice model predicts that there will be differences in choice behavior, only to a lesser degree than if a_2 were 0 in the orange conditions. That is, the model predicts that (a) choice of the alternative that delivers more frequent terminal links will be greater in the orange conditions than in the green-red conditions, (b) this difference between orange and green-red conditions will be greater with longer terminal links, and (c) terminal-link duration will have less effect on choice in the orange conditions.

METHOD

Subjects

Four White Carneau pigeons were maintained at about 80% of their free-feeding

weights. All had previous experience with a variety of experimental procedures, including concurrent-chains procedures similar to the one used in the present experiment.

Apparatus

The experimental chamber was 30 cm long, 30 cm wide, and 33 cm high. Three response keys, each 2.5 cm in diameter, were mounted in the front wall of the chamber, 23.5 cm above the floor and 8 cm apart, center to center. A force of approximately 0.15 N was required to operate each key, and each effective response produced a feedback click. Each key could be transilluminated with lights of different colors. A hopper below the center key provided controlled access to grain, and when grain was available, the hopper was illuminated with a 2-W white light. Eight 2-W lights of different colors were mounted in a row above the wire-mesh ceiling, along the back wall of the chamber. The colors were arranged symmetrically from the center of the row outward, with two white lights in the center of the row, flanked by two green lights, two red lights, and finally two orange lights at the ends of the row. The chamber was enclosed in a sound-attenuating box containing a ventilation fan. All stimuli were controlled and responses recorded by an IBM-compatible personal computer using the Medstate® programming language.

Procedure

The experiment consisted of 13 conditions. All sessions lasted 60 min, and were usually conducted 6 days per week. Throughout the experiment, a concurrent-chains procedure was used, in which a single VI 20-s schedule operated in the initial links, and the terminal links were FT schedules that delivered food reinforcers on a probabilistic basis.

During the initial links of the concurrent chain, the white houselights were on, and the two side keys were illuminated, the left key green and the right key red. A single VI 20-s timer assigned opportunities to enter the terminal links to the two keys on a random basis (cf. Stubbs & Pliskoff, 1969), according to a percentage that varied across conditions. A 2-s changeover delay was in effect during the initial links, such that no response could produce a terminal-link entry until at least 2 s had elapsed after a switch from one key to the other. Once a terminal-link entry was assigned to one of the two keys, the VI timer stopped and did not restart until that terminal link was entered and completed.

Table 1

Order of experimental conditions.

Houselight colors	Percentage left TLs	Percentage TLs with food		TL duration	Order for subjects	
		Left	Right		1 and 2	3 and 4
orange	50	50	50	5	1	1
orange	20	80	20	5	2	3
orange	80	20	80	5	3	2
orange	20	80	20	5	4	5
orange	80	20	80	5	5	4
orange	80	20	80	15	6	7
orange	20	80	20	15	7	6
green-red	80	20	80	15	8	9
green-red	20	80	20	15	9	8
green-red	80	20	80	5	10	11
green-red	20	80	20	5	11	10
green-red	80	20	80	2	12	13
green-red	20	80	20	2	13	12

Note. Durations are in seconds. TL = terminal link.

In the first seven conditions of the experiment (the orange conditions), the same orange houselights were used for both the left and right terminal links. Upon entry into a terminal link, the keylights and white houselights were turned off, and the orange houselights were lit. When the FT schedule was completed, the orange houselights were turned off, and food was presented on some trials but not others. When an FT trial ended with food, the white light above the food hopper was lit, and grain was presented for 3 s. When an FT trial did not end with food, the orange houselights were replaced with white houselights, the green and red keylights were lit, and the next initial link began.

In the last six conditions of the experiment (the green-red conditions), green houselights were lit during the left terminal links, and red houselights were lit during the right terminal links. As in the orange conditions, some terminal links ended with a 3-s food presentation, and some did not. In all other respects, the procedure was identical to that of the orange conditions.

Table 1 lists the reinforcement percentages and terminal-link durations for each condition. In the first condition, each key delivered 50% of the terminal links, and 50% of all ter-

minal links ended with food. In all the remaining conditions, one key delivered 80% of the terminal links, but only 20% of these terminal links ended with food. The other key delivered 20% of the terminal links, but 80% of these terminal links ended with food. Therefore, the average number of food reinforcers was equated for the two alternatives, but the number of terminal-link entries was not. Terminal-link durations were either 5 s or 15 s in different orange conditions, and they were either 2 s, 5 s, or 15 s in different green-red conditions. Note that one order of conditions was used for Birds 1 and 2 and a different order was used for Birds 3 and 4.

All conditions lasted for a minimum of 20 sessions. For each session, the percentage of initial-link responses on the left key was calculated. After 20 sessions, a condition was terminated for each subject individually when the following stability criteria were met: (a) Neither the highest nor the lowest single-session response percentage could occur in the last six sessions of a condition. (b) The mean response percentage across the last six sessions could not be the highest or the lowest six-session mean of the condition. (c) The mean response percentage of the last six sessions could not differ from the mean of the preceding six sessions by more than 5%.

RESULTS

The number of sessions required to meet the stability criteria ranged from 20 to 45 (median = 22.5 sessions). For each subject and each condition, Figure 1 shows the mean percentage of responses on the left key during the last six sessions of each condition (the sessions that met the stability criteria described above).

In the first condition, in which the schedules were identical for the two keys, subjects made an average of 43.7% of their responses on the left key, suggesting a slight bias toward the right key. This was the only condition to make a direct assessment of key bias, and bias could change over the course of the experiment. However, the mean response percentages suggest that the small bias for the right key continued through the experiment. Averaged across all orange conditions, 47.6% of the responses were on the left key, compared to 44.2% in the green-red conditions. To compensate for key bias as much as possible, all conditions after Condition 1 were conducted in pairs in which the reinforcement contingencies for the two keys were reversed. The difference in left-key response percentages across the two conditions of each pair can therefore be used to estimate the degree of preference for one set of reinforcement contingencies versus the other.

In the remaining six conditions with orange houselights, subjects showed a small but consistent preference for whichever alternative delivered more orange terminal-link entries. For convenience, conditions in which the left schedule delivered 20% of the terminal links will be called the *20% conditions*, and those in which the left schedule delivered 80% of the terminal links will be called the *80% conditions*. A repeated measures analysis of variance conducted on the results from all orange conditions found a significant effect of condition, $F(6, 18) = 6.14$, $p < .001$. A planned comparison found a significant difference between the 20% and 80% conditions, $F(1, 18) = 37.08$, $p < .001$. For every subject, the percentage of left responses was always higher in the 80% conditions compared to the 20% conditions that preceded or followed (although in a few cases the differences were very small).

For the group as a whole, the results from the orange conditions were quite similar with 5-s and 15-s terminal links. With 5-s terminal links, the percentages of left responses were 43.9% and 54.5% in the 20% and 80% conditions, respectively. The corresponding response percentages with 15-s terminal links were 40.4% and 52.1%. Thus the degree of preference for the schedule that delivered more terminal links was approximately the same with 5-s and 15-s terminal links, as predicted by the contextual choice model. Two planned comparisons comparing the orange conditions with 5-s versus 15-s terminal links found no significant differences: For the 20% conditions, $F(1, 18) = 1.38$, and for the 80% conditions, $F(1, 18) = 0.63$. Figure 1 shows that there was no consistent pattern in preference between the two durations for individual subjects.

The results from the green-red conditions were different in two respects. First, in the conditions with 15-s terminal links, all subjects showed a higher response percentage

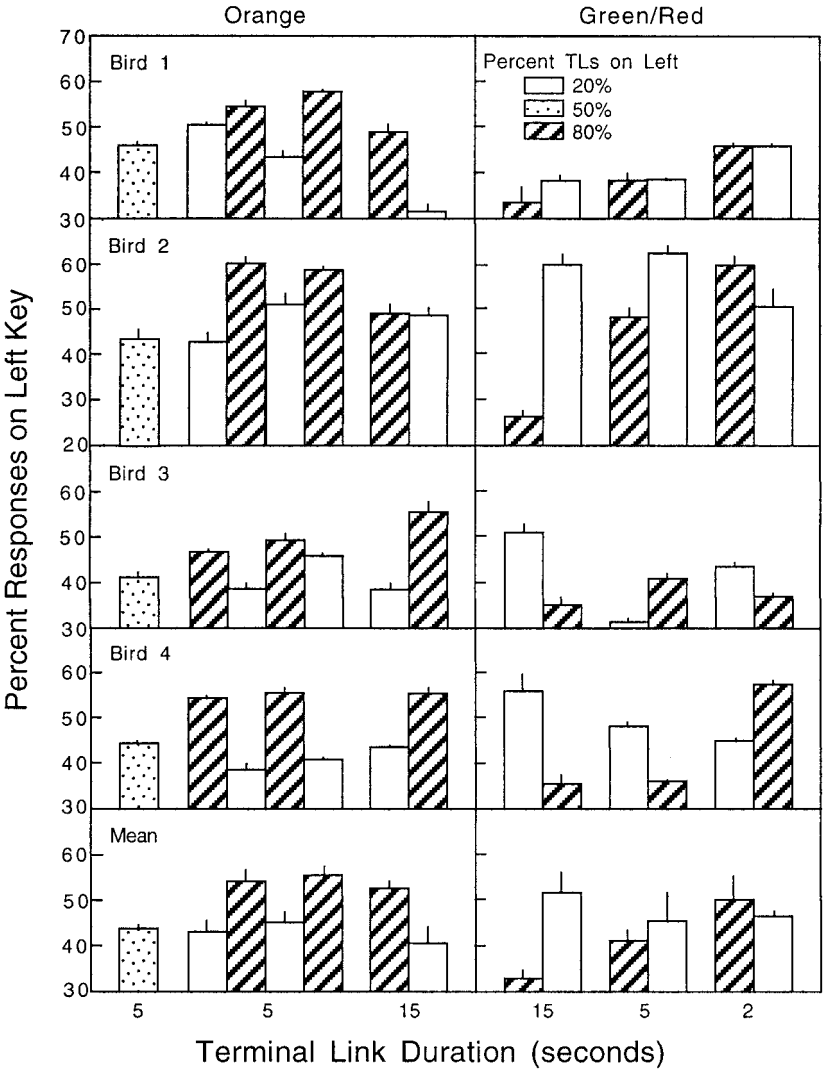

Fig. 1. The mean percentage of responses on the left key in the six sessions that satisfied the stability criteria is shown for each subject and each condition. The error bars show one standard error of the mean. For each subject, the conditions are displayed in their order of presentation. Note that the range of percentages shown on the *y* axis is different for different subjects.

for the left key when it delivered only 20%, rather than 80%, of the terminal links. Second, the degree of preference varied with terminal-link duration: The greatest differences in response percentages between the 20% and 80% conditions were found with 15-s terminal links, and there were no consistent differences between the 20% and 80% conditions with the 5-s and 2-s terminal links. A two-way repeated measures analysis of variance using the results from all green-red conditions found no significant main effect of either terminal-link probability, $F(1, 3) = 2.99$, or terminal-link duration, $F(2, 6) = 1.63$. However, there was a significant interaction between terminal-link probability and duration, $F(2, 6) = 9.96$, $p < .05$. This interaction reflects the change in preference across the different terminal-link durations shown in Figure 1, and it is generally consistent with the predictions of the contextual choice model.

A better perspective on factors that affected choice in this situation can be obtained by

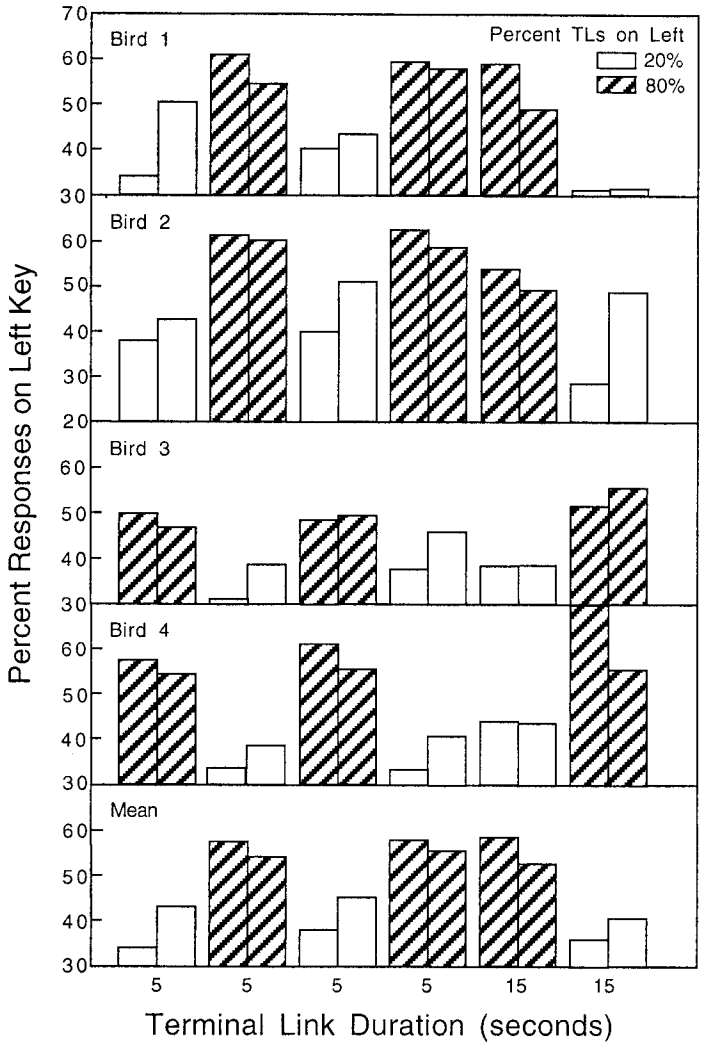

Fig. 2. Each pair of bars shows the percentage of responses on the left key in the first six sessions of a condition (left bar) and in the six sessions that satisfied the stability criteria (right bar). The data are from Orange Conditions 2 through 7, displayed in their order of presentation for each subject. Note that the range of percentages shown on the *y* axis is different for different subjects.

examining the changes that occurred from the beginning to the end of each condition. Notice that, except for the transition from Condition 5 to Condition 6, the side that delivered more terminal links was switched at the start of each condition. Therefore, at the start of every condition except Condition 6, there were simultaneous changes in (a) which side delivered more terminal links and (b) which side's terminal links had the higher probability of ending with food.

Figure 2 compares the left response percentages at the beginning and end of each orange condition (except for the first condition, which had 50% reinforcement for both alternatives). The first bar is the left response percentage from the first six sessions of each condition, and the second bar is from the last six sessions (the same data as in Figure 1). On average, the percentage of responses for the side that delivered 80% of the terminal links was 61.0% in the first six sessions of a condition and 55.5% in the last six sessions. This is not a large difference, but Figure 2 shows that in 20 of 24 cases, choice percentages for whichever side delivered 80% of the

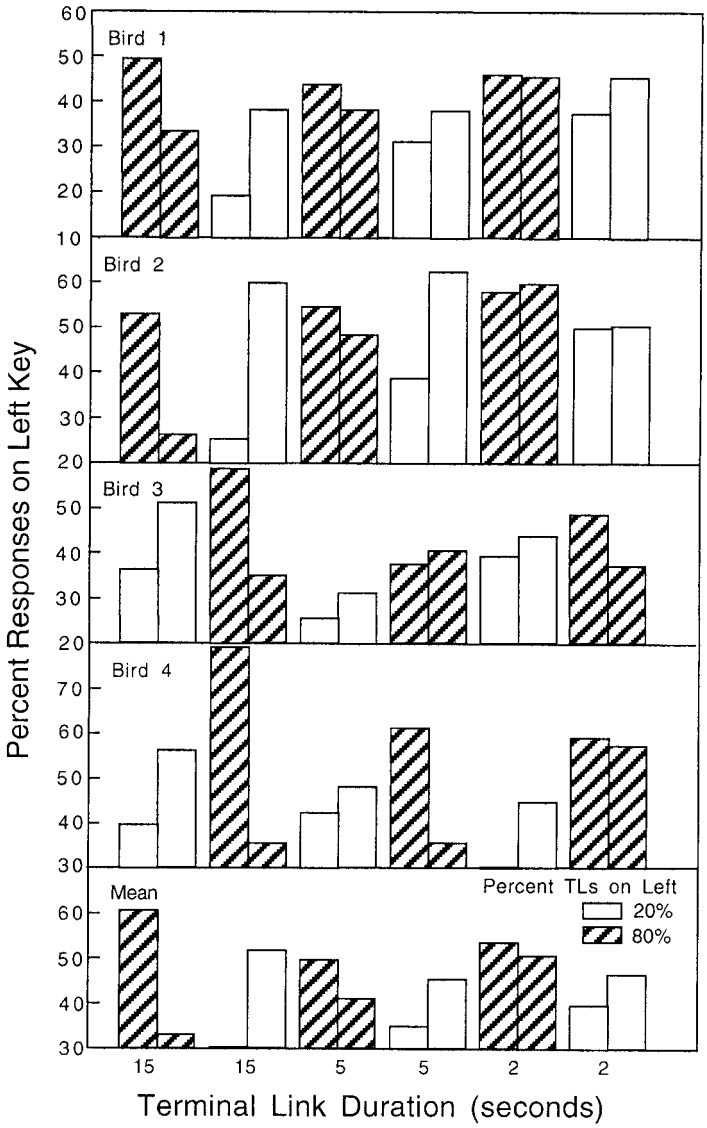

Fig. 3. Each pair of bars shows the percentage of responses on the left key in the first six sessions of a condition (left bar) and in the six sessions that satisfied the stability criteria (right bar). The data are from the green-red conditions, displayed in their order of presentation for each subject. Note that the range of percentages shown on the *y* axis is different for different subjects.

terminal links were greater at the beginning of a condition than at the end of the condition ($p < .01$, two-tailed sign test). This finding indicates that the frequency of terminal-link entries had a greater effect on subjects' choices at the beginning of each condition. As the condition proceeded, however, the pigeons evidently learned that a smaller portion of terminal links ended with food for this alternative, and choices for this schedule tended to decrease.

This difference between the beginning and end of a condition was more pronounced in the green-red conditions, as shown in Figure 3. On average, the percentage of responses for the side that delivered 80% of the terminal links was 59.7% in the first six sessions of a condition and 46.8% in the last six sessions.

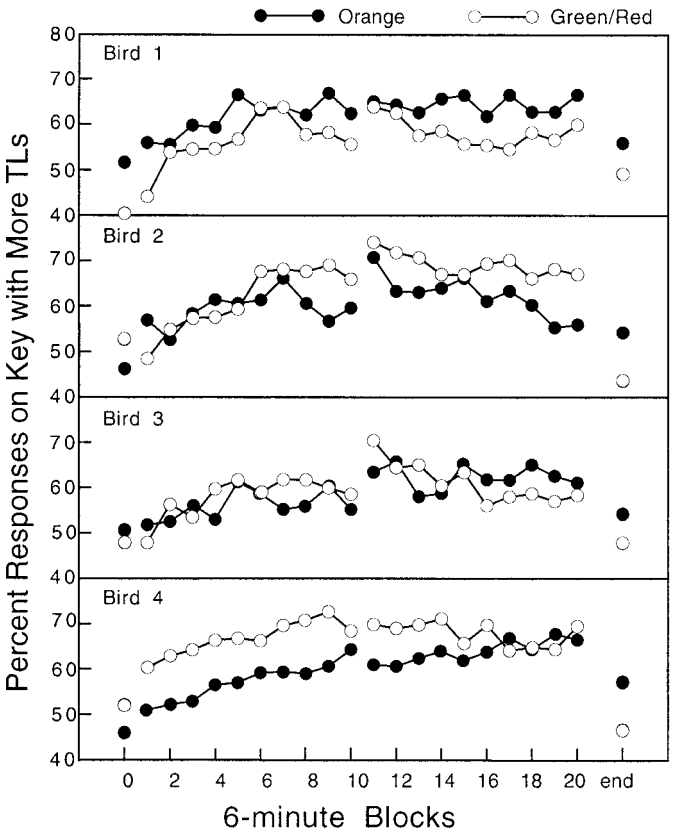

Fig. 4. The percentage of responses on the key that delivered more terminal links is shown for successive 6-min blocks from the first two sessions of a condition. The data are averaged across Orange Conditions 2 through 7 and across all six green-red conditions. The data points at Block 0 are the mean percentages from the last 6-min block of the preceding condition. The data points labeled "end" are the mean percentages from the six sessions that satisfied the stability criteria in each condition.

In 22 of 24 cases, there was greater preference for the side that delivered 80% of the terminal links at the beginning of a condition than at the end of the condition, ($p < .001$, two-tailed sign test). In a number of cases, especially with 15-s terminal links, there was a reversal in preference across a condition: Subjects showed a preference for the side that delivered 80% of the terminal links in the first six sessions, but they showed a preference for the other side in the last six sessions. For example, see Birds 3 and 4 when 80% of the terminal links were on the left, and Bird 2 when 20% of the terminal links were on the left.

Because the side that delivered more terminal links changed at the start of every condition except Condition 6, a closer analysis of choice responses in the first few sessions of a condition should show the initial effects of this change. To examine such effects, the results from the first two sessions of each condition (except Condition 1) were divided into 6-min blocks. To reduce the variability in such small time samples, the results from Conditions 2 through 7 (the orange conditions) were averaged together, as were the results from Conditions 8 through 13 (the green-red conditions). For each subject, Figure 4 shows the mean percentage of responses on the key that delivered 80% of the terminal links, from successive 6-min blocks of the first two sessions of a condition. For comparison, the leftmost data points are the mean response percentages from the last 6-min block of the previous condition, and the rightmost data points are the means from the last six sessions of each condition (those presented for indi-

vidual conditions in Figure 1). Despite some variability in the data, in general the results from the first session (Blocks 1 through 10) show an increase in response percentages for the key that delivered 80% of the terminal links. By the second session of a new condition (Blocks 11 through 20), however, there were little or no further increases in preference for this key, and for Bird 2 the response percentages began to decline. In all cases, the response percentages at the end of the condition were lower than in the second session.

Taken together, the results from Figures 2, 3, and 4 revealed the following pattern: When the side that delivered 80% of the terminal links was switched at the start of a new condition, subjects showed a rapid increase in response percentages for this side (with most of the increase appearing in the first session). Response percentages for this side then gradually declined, and in about 90% of the cases, response percentages were lower during the last six sessions of the condition than in the first six sessions.

DISCUSSION

Because the terminal links of a concurrent-chains schedule lead to a primary reinforcer (at least some of the time), it has been traditional to think of the terminal-link stimuli as conditioned reinforcers (e.g., Fantino, 1977). This experiment provides several pieces of information about how these conditioned reinforcers affect choice responding. In both the orange and green-red conditions, the initial effect of a change in the terminal-link percentages was an increase in preference for the key that now delivered more frequent terminal links. This increase can indeed be considered a reinforcement effect—an increase in response percentages for the key that delivered more frequent terminal links.

Much of this effect was short-lived, however: As a condition continued (and as subjects presumably learned that the additional terminal links did not end with food reinforcers), response percentages for the key that delivered more terminal links decreased. The amount of decrease depended on the types and durations of stimuli used during the terminal links. In the green-red conditions, there was a reversal of preference in some cases (especially when terminal links were 5 s or longer), such that by the end of a condition subjects showed a preference for the alternative that delivered fewer terminal links but had a higher percentage of terminal links that ended with food. This result is consistent with the common view that the strength of a conditioned reinforcer is inversely related to its duration (e.g., Mazur, 1995, 1997; Vaughan, 1985).

In the orange conditions, a slight preference for the alternative that delivered more frequent terminal links was still observed at the end of most conditions. This result replicates the findings of Williams and Dunn (1991), and as these authors suggest, this result can be treated as evidence for conditioned reinforcement. Yet when compared to the results of the green-red conditions, this conditioned reinforcement effect might best be viewed as a result of a weaker discrimination between the two terminal links and their respective probabilities of delivering food (due, of course, to the fact that both terminal links were associated with the same stimulus).

Grace's (1994) contextual choice model provides a useful framework for understanding these results, and the model's predictions were generally consistent with the results. According to this model, two opposing factors are at work in this choice situation: (a) One alternative delivers a greater frequency of terminal links, but (b) the probability (or rate) of food during this alternative's terminal links is lower. A subject's preference for one alternative or the other will depend on which of these two factors has greater impact. The model accounts for the results of this experiment as follows. In the orange conditions, sensitivity to the differing rates of food in the two terminal links (as reflected in the exponent a_2 in Equation 1) was presumably low because the same stimulus was used in both terminal links. Therefore, the relative frequency of terminal-link entries (r_{1L}/r_{1R}) was the dominant factor, and subjects showed a preference for the alternative that delivered more frequent terminal-link entries.

In contrast, a_2 was presumably greater in the green-red conditions because different stimuli were used in the two terminal links. It follows from Equation 1 that if a_2 is large enough, subjects might now show a preference for the side that delivers fewer terminal

links, because the rate of food deliveries (as reflected in the ratio r_{2L}/r_{2R}) was greater during this side's terminal links. For all 4 subjects, left choice percentages in the 15-s green-red conditions were higher when the left schedule delivered only 20% of the terminal links.

The contextual choice model also predicts that terminal-link duration should affect choice in the green-red conditions because of changes in T_l/T_i, the ratio of the mean terminal-link and initial-link durations. This ratio is an important feature of the contextual choice model, because it allows the model to predict the so-called ''terminal-link effect''—that terminal-link schedules have a greater effect on preference when their durations are longer (e.g., MacEwen, 1972; Williams & Fantino, 1978). For the green-red conditions of the present experiment, this factor leads to the prediction that response percentages for the side that delivers more frequent terminal links (but has a lower rate of food delivery per terminal-link entry) will increase as terminal-link duration decreases. Consistent with this prediction, left-key response percentages were higher in the 80% conditions with 2-s terminal links than in those with 15-s terminal links. The results from the conditions with 5-s terminal links should fall between those with 15-s and 2-s terminal links, but Figure 1 shows that there were no consistent differences between the green-red conditions with 5-s versus 2-s terminal links. Perhaps the change from 5-s to 2-s terminal links was not large enough to produce consistent changes in choice behavior. Note, however, that the group means from the 5-s green-red conditions do fall between those of the 2-s and 15-s conditions.

The results of this experiment, along with those of previous similar studies, suggest that the term *conditioned reinforcer* can sometimes be a misnomer when applied to terminal-link stimuli in concurrent-chains schedules. By definition, a reinforcer must strengthen responding. In the present experiment, increasing the number of terminal-link stimuli without increasing the number of food presentations did lead to an initial increase in preference, but in the green-red conditions this preference soon disappeared in most cases. Increasing the number of terminal-link stimuli produced a long-term increase in preference only in the orange conditions, in which the same stimulus was used for both terminal-link schedules. These results suggest that increasing the number of terminal-link stimuli without increasing the number of primary reinforcers will produce an increase in preference only in certain circumstances. The present experiment identified three such circumstances: (a) when there is a sudden increase in the number of terminal-link stimuli, but before subjects learn that there is no increase in primary reinforcement; (b) when the same terminal-link stimulus leads to a low probability of primary reinforcement for one alternative but a higher probability for another alternative, and subjects may therefore have difficulty discriminating between the two terminal links; and (c) when terminal-link duration is short relative to initial-link duration, as expressed in the ratio T_t/T_i in Grace's (1994) contextual choice model.

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